Report No. CG-D-05-96

Ohmsett Tests of:

The CANFLEX "Sea Slug" Temporary Storage Device and the DOAS Flotation Collar

Michael Goodwin
and
Roland L. Custer

MAR, Incorporated
6110 Executive Boulevard, Suite 410
Rockville, Maryland 20852

FINAL REPORT
April 1995

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

Prepared for:

U.S. Coast Guard
Research and Development Center
1082 Shennecossett Road
Groton, Connecticut 06340-6096

and

Canadian Coast Guard
Environmental Response and Emergency Planning
Ottawa, Ontario, Canada

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

The contents of this report reflect the views of the Coast Guard Research & Development Center. This report does not constitute a standard, specification, or regulation.

G. T. Gunther
Technical Director, Acting
United States Coast Guard
Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

Technical Report Documentation Page

1. Report No. CG-D-05-96	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Ohmsett Tests of: The CANFLEX "Sea Slug" Temporary Storage Device and the DOAS Floatation Collar		5. Report Date April 1995
		6. Performing Organization Code
7. Author(s) Michael Goodwin and Roland L. Custer		8. Performing Organization Report No. R&DC 40/95
9. Performing Organization Name and Address MAR, Incorporated 6110 Executive Boulevard, Suite 410 Rockville, MD 20852		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
		13. Type of Report and Period Covered Final Report
12. Sponsoring Agency Name and Address U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, Connecticut 06340-6096	Canadian Coast Guard Environmental Response and Emergency Planning Ottawa, Ontario, Canada	14. Sponsoring Agency Code

15. Supplementary Notes

This report was developed under the technical supervision of Kenneth R. Bitting at the U.S. Coast Guard Research and Development Center and John Latour at the Canadian Coast Guard.

16. Abstract

This report describes an initial series of tests of the CANFLEX "Sea Slug" temporary storage device and the DESMI Offload Adapter System (DOAS). The tests were primarily of two types, 1) tests of the effectiveness of offloading techniques with the DOAS, and 2) tests of the time required for oil and water to separate within the "Sea Slug." A third area of interest was determination of cleaning techniques for the "Sea Slug."

After the initial series of tests, it was concluded that an additional method of offloading should be investigated. This consisted of a pump lowered to the bottom mid-length along the "Sea Slug." This report includes the results of these tests, as well.

17. Key Words temporary storage device oil spill recovery equipment	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. SECURITY CLASSIF. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

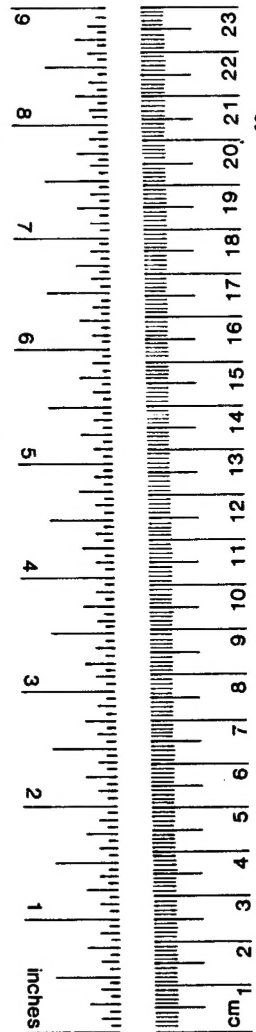
Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

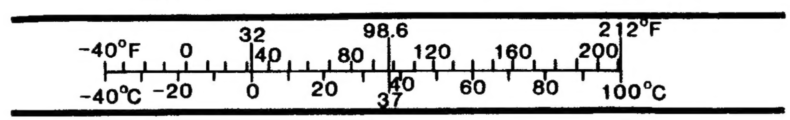
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Sponsors of the testing included the Minerals Management Service represented by Larry Hannon and the U.S. Coast Guard Research and Development Center represented by Ken Bitting and James Vicedomine. With their assistance the testing flowed smoothly.

The assistance of CW02 Barry Brouhard from the U.S. Coast Guard Headquarters, Civil Engineering Division, Ocean Engineering Branch, Response Systems Section in operating and trouble-shooting the supplied equipment was greatly appreciated and instrumental in completing the testing. Wes Udell of CANFLEX provided insight on the "Sea Slug" and Mr. Flemming Hvidbak of DESMI provided insight on the operation of the DOAS.

The testing program was a team effort and the Ohmsett staff was fully involved in the tests. The staff members are listed alphabetically below:

Burrowes H. Aumack
Donald Backer
James Z. Butkowski
Susan Cunneff
David DeVitis
Scott McHugh
Kevin McLavish
Jim Nash
John J. Reseter
Robert A. Vitale
Tamara Zemlanicky

TABLE OF CONTENTS

Section **Page**

TABLES

FIGURES

1 INTRODUCTION

1.1 Purpose of the Tests

The CANFLEX "Sea Slug" temporary storage device was tested at Ohmsett to evaluate offloading techniques using the DESMI Offload Adapter System (DOAS) and using a centrally located pump. Two other areas were examined: the separation time of the oil/water mixture inside the "Sea Slug" and techniques for cleaning the "Sea Slug."

The term "Decanting Tests" is used in this report to describe the oil/water separation tests performed. These tests were performed to determine the feasibility of decanting off excess sea water while at sea to permit more skimmed oil to be added to the temporary storage device. The term "decanting" is often used to refer to: 1) the settling process or time during which oil and water separate by gravity; and 2) the act of removing the water from the bottom after the settling process has occurred. The decanting tests documented in this report address only the definition above.

1.2 Background

The U. S. Coast Guard is currently evaluating oil spill response equipment that has the potential to help the Coast Guard's National Strike Force (NSF) effectively respond to oil spills at sea. One class of equipment being evaluated is Temporary Storage Devices (TSD). The combination of a CANFLEX "Sea Slug" towable temporary storage device and a DESMI Offload Adapter System (DOAS) was identified as a potentially useful combination for temporary storage, transport, and shore-side offload of recovered oil and water.

The Canadian Coast Guard (CCG) is also evaluating new equipment for oil spill response operations. The CCG and USCG combined resources to conduct more cost-efficient testing. The CCG provided the "Sea Slug" and the USCG provided the Ohmsett facility and the pump system for offloading.

At sea tows of the "Sea Slug" were conducted on June 8, 1993, out of New London, Connecticut. The Naval Undersea Warfare Center's support ship "TROJAN" towed the 25,000 gallon "Sea Slug" full of salt water at speeds up to 4.8 knots at which speed the bag started to submerge. For the next testing phase, the "Sea Slug" with DOAS was tested at Ohmsett to investigate offloading techniques and decanting times.

After the tests with the DOAS at Ohmsett in August 1993, it was concluded that a further offloading technique should be investigated. As a result, tests were conducted in August 1994 using a centrally located offloading pump. Both series of Ohmsett tests are included in this report.

1.3 Objectives of the Tests

The test objectives with the combination of the "Sea Slug" and DOAS were to:

(1) determine the effectiveness in offloading with the DOAS only;
(2) determine the effectiveness in offloading with "Sea Slug" being dragged over a raised fairlead;
(3) determine the effectiveness in offloading using weight or buoyancy to concentrate the oil;
(4) determine the effectiveness in offloading with a crane lift assist;

(5) determine the decanting effectiveness of the "Sea Slug"; and
(6) investigate cleaning techniques for the "Sea Slug."

Note the DOAS was not a direct participant of the decanting test, but was used to offload the oil/water mixture after the test.

A later series of offloading tests was conducted with the Kvaerner Eureka CCN 150 submersible pump mounted at the bottom mid-length of the "Sea Slug." These tests were used to determine the effectiveness of this system in offloading.

1.4 Scope of Tests

The offloading tests with the DOAS were conducted with the "Sea Slug" loaded with approximately 10,000 gallons, 40% full, of 50,000 cSt oil. The 50,000 cSt oil was a goal and heated tanks were necessary to meet this goal. The "Sea Slug" was supported by placing it in the Ohmsett basin. The DOAS was configured to offload the oil back into the heated tanks. Later tests with the centrally located CCN 150 were conducted with an oil/water mixture from the oil storage tanks at Ohmsett. Between 8,000 and 9,500 gallons of fluid were used in each of these tests. A viscosity between 15,000 cSt and 30,000 cSt was the goal for the centrally located pump tests.

The first test was offloading the "Sea Slug" with DOAS only. The other DOAS offloading tests involved assisting the offloading by changing the physical attitude of the "Sea Slug." One way this was accomplished was by using the crane to lift the end opposite the DOAS. The maximum load on the crane was not to exceed 12,000 pounds. Another method of changing the geometry of the "Sea Slug" was placing 2,000 pounds of weight on the bow. The final method was to simulate the "Sea Slug" being dragged onto the stern of a vessel, bow first. All the methods tested were designed to move the oil in the "Sea Slug" close to the offloading pump. The TSD was inflated with air for the centrally located pump tests. Also, approximately 500 pounds of added flotation was attached to each end of the TSD to simulate the latest design configuration. Together with the weight of the pump at mid-length, this flotation and the air pressure were expected to help the oil to flow to the pump as the TSD emptied.

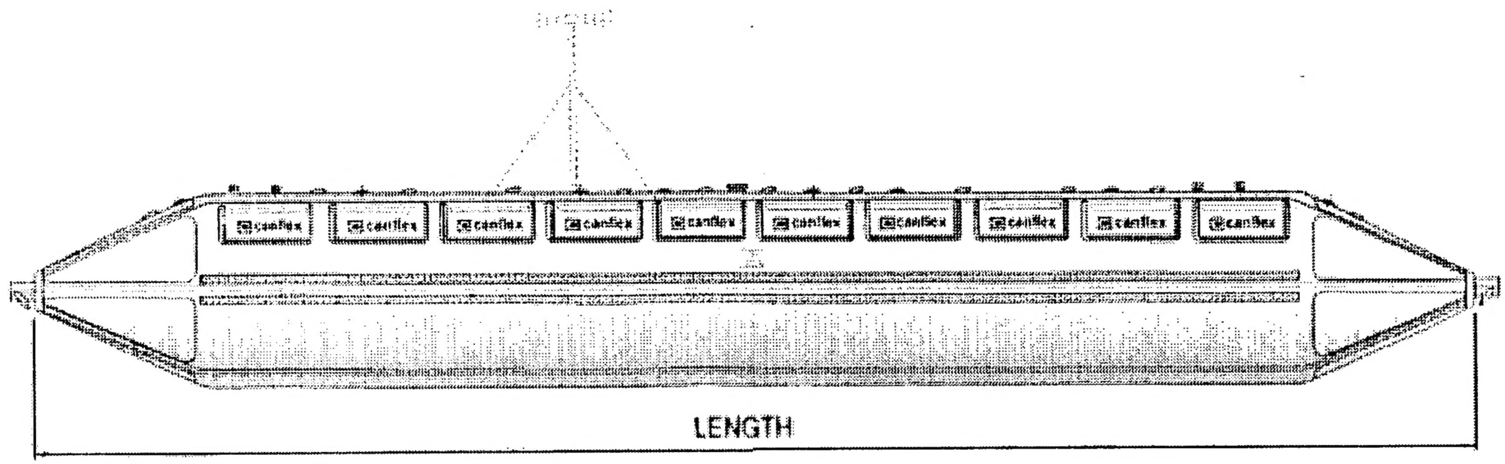
The decanting test consisted of filling the "Sea Slug" to 83 percent full with a mixture of light oil and water, 57 percent oil and 43 percent water. The oil and water were mixed as the "Sea Slug" was loaded. To help keep the mixture in a mixed state, the "Sea Slug" was subjected to a harbor chop sea condition while being filled. The harbor chop was stopped and samples at different heights in the "Sea Slug" were taken every 15 minutes for an hour.

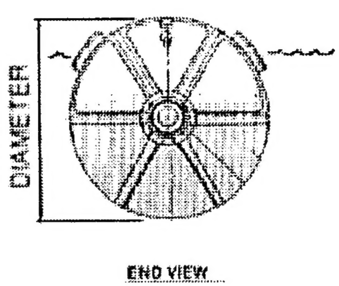
1.5 Description of Equipment

1.5.1 Equipment Under Test

The equipment tested consisted of two separate assemblies that were married together for these tests. The two assemblies for the initial series of tests were the CANFLEX "Sea Slug" temporary storage device and the DESMI Offloading Adapter System, DOAS. The second offloading test series married the "Sea Slug" with an Eureka CCN 150 pump.

The CANFLEX™ "Sea Slug" Model FCB 250, shown in Figure 1, is a cylindrical fabric bag with conical ends, 65'-9" long and 8'-9" in diameter with a nominal capacity of 25,000 U.S. gallons of





"SEA SLUG" — SERIES II

MODEL	CAPACITY (US Gals)	DIAMETER	LENGTH	AUXILIARY FLOATATION	SHIPPING WEIGHT
FCB 50	5,000	4'-3/4" (48 3/4")	55'-3"	1200 lbs	1350 lbs
FCB 100	10,000	8'-9" (105")	35'-0"	1440 lbs	1900 lbs
FCB 250	25,000	8'-9" (105")	65'-9"	4800 lbs	3000 lbs

Figure 1 "Sea Slug" Temporary Storage Device

liquid. The temporary storage device is made of PVC coated polyester fabric with a urethane liner. It is supported in the water when empty by 20 blocks of flexible closed cell foam inside fabric enclosures attached to the bag. The forward end connection is a cast aluminum cone with a 3" pipe fitting mounted on a plate. The after end connection is identical except the plate is replaced with one having a 10" flanged pipe which bolts to the DOAS valve. The DOAS was used to empty the bag. Along the top of the bag are a number of pressure relief valves and 4" filling connections as well as a 16" plate that is centrally located. The plate has a 6" female camlock fitting mounted on it. This fitting is the main fill connection point for the "Sea Slug."

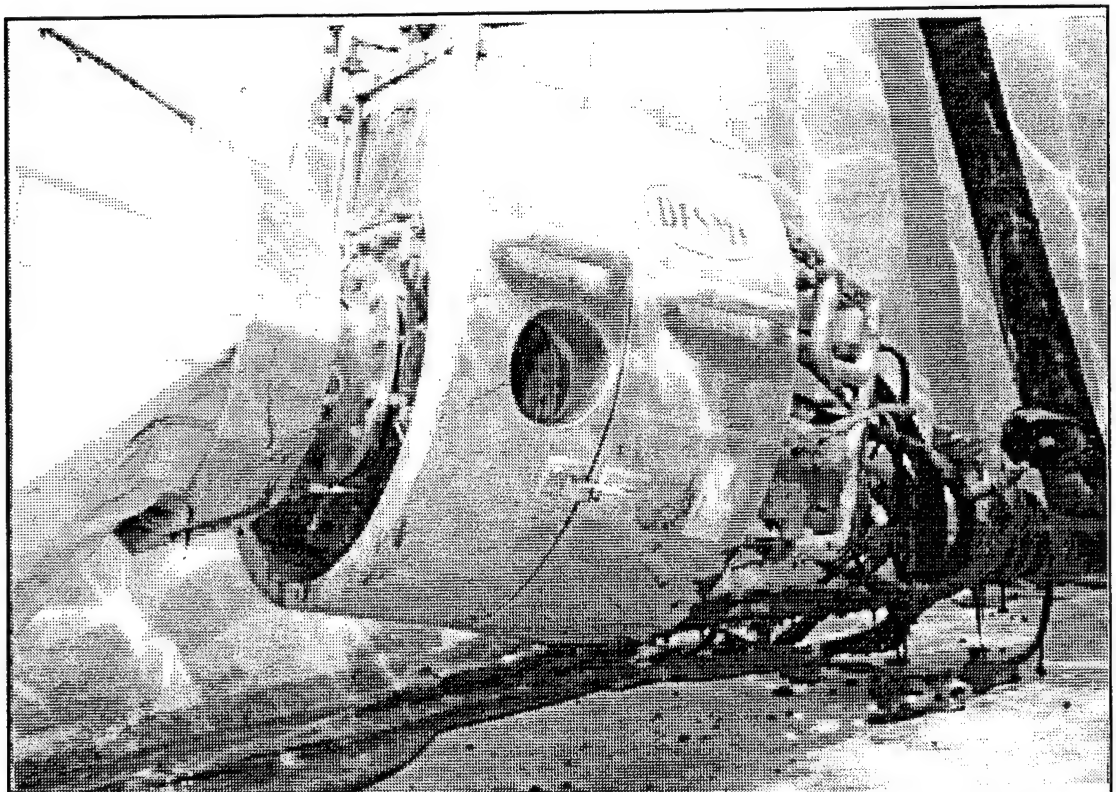


Figure 2 DOAS Attached to "Sea Slug"

The DOAS is shown in Figure 2, an underwater photograph of the DOAS attached to the "Sea Slug." The DOAS provides a knife gate valve, a DESMI DOP-250 pump, and a hydraulic control station for operating the system and interfacing with a hydraulic power source. The DOAS consists of two separate units mechanically and hydraulically joined together, (1) a hydraulically operated knife valve with a flotation collar (nearest to the temporary storage device) and (2) a DESMI DOP-250 pump inside a flotation collar. The two units are close-coupled with a 10" camlock fitting connecting the piping. The flotation collars are connected together by latches. The DOAS assembly mounts to the "Sea Slug" by means of a bolted 10 inch pipe flange.

The DESMI DOP-250 pump is a hydraulically powered Archimedean - screw pump designed for pumping highly viscous oils. Its nominal capacity is 250 gallons per minute. The hydraulic power for both the pump and valve was provided during testing by a diesel driven unit that is part of the U.S. Coast Guard's Vessel of Opportunity Skimming System (VOSS) equipment. The control of both pump and valve was via a prototype Remote Control Station that connected the hydraulic power unit to the pump and valve. It controlled pump direction and speed along with the valve opening and closing.

The DOP-250 pump discharge has a 5" DESMI Mod 42 male coupling fitting with a quick disconnect stem for 6" hose. Hydraulic supply and return lines for the pump are 1" nominal diameter and the drain line is 3/8" diameter. The knife valve hydraulic lines are 1/4" with a 3/8" check line. These lines are connected to the Remote Control Station.

In the Centrally Located Pump Offloading Tests, the CCN 150 pump was mounted as shown in Figure 3 through the top center opening in the "Sea Slug." The center plate on the top of the TSD was modified for this test. The existing 16 inch diameter ring was replaced by a 20 inch outside diameter, 16 inch inside diameter ring. A support plate was fabricated to bolt on top of the new ring. This support plate had connections for the pump discharge pipe, hydraulic connections and an air supply line for pressurizing the bag. The CCN 150 pump was suspended from this plate by two cable lanyards so that it was just at the bottom of the fully inflated bag.

1.5.2 Support Equipment

Figure 4 shows the plan view of the support equipment setup for the initial tests. The equipment used in support of testing was the Kvaerner Eureka a.s. CCN 150 centrifugal submersible pump; the VOSS control station; the diesel driven hydraulic power pack; two 5,500 gallon insulated heated tanks; and a 3 inch static mixer. The CCN 150 pump was used to transfer oil from the two 5,500 gallon heated tanks to the "Sea Slug." The tanks also received the oil offloaded by the DOAS from the "Sea Slug." The VOSS remote control station controlled the hydraulic power from the diesel hydraulic power pack to the CCN 150 pump.

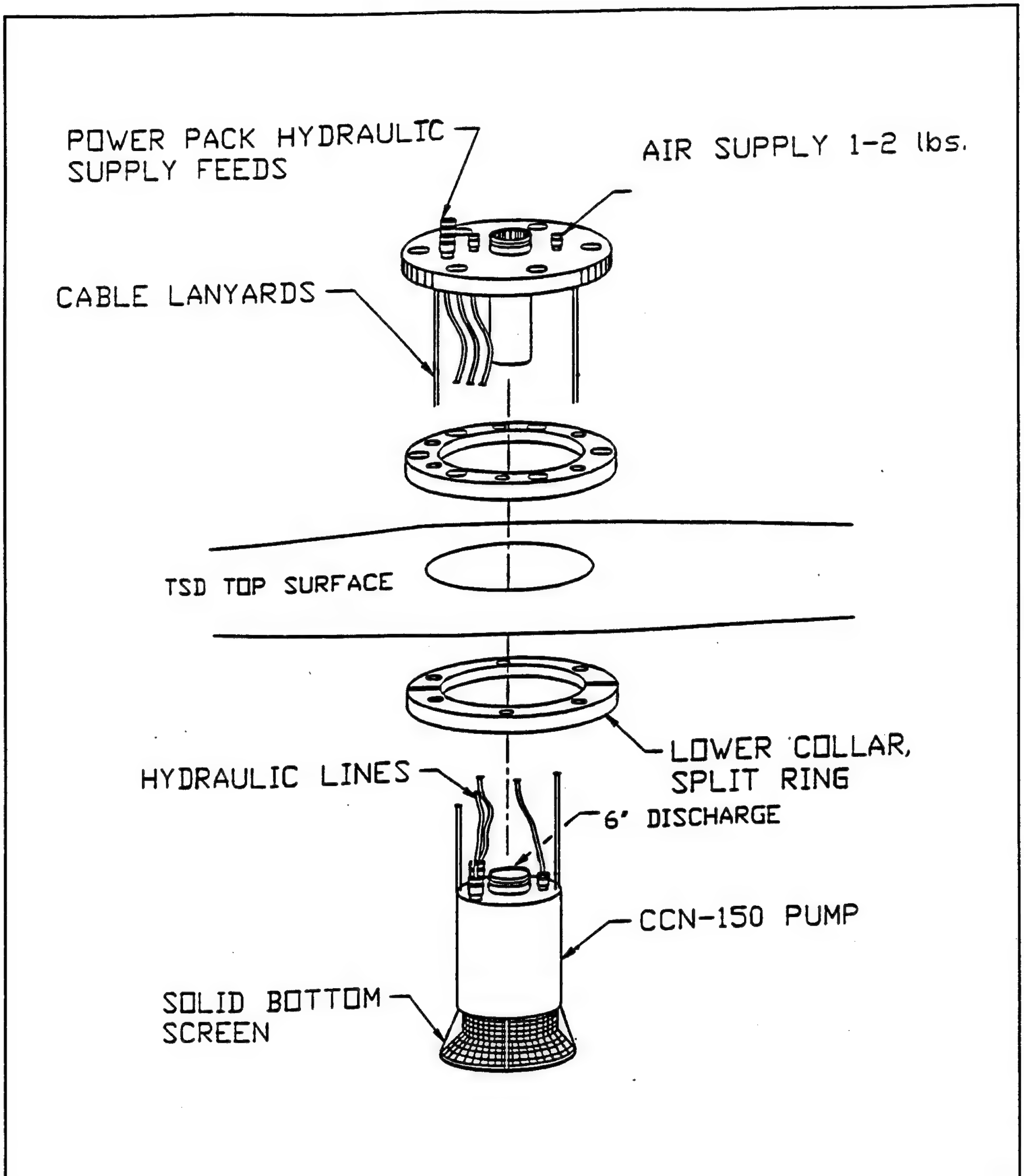


Figure 3 Arrangement for CCN 150 Pump Installation

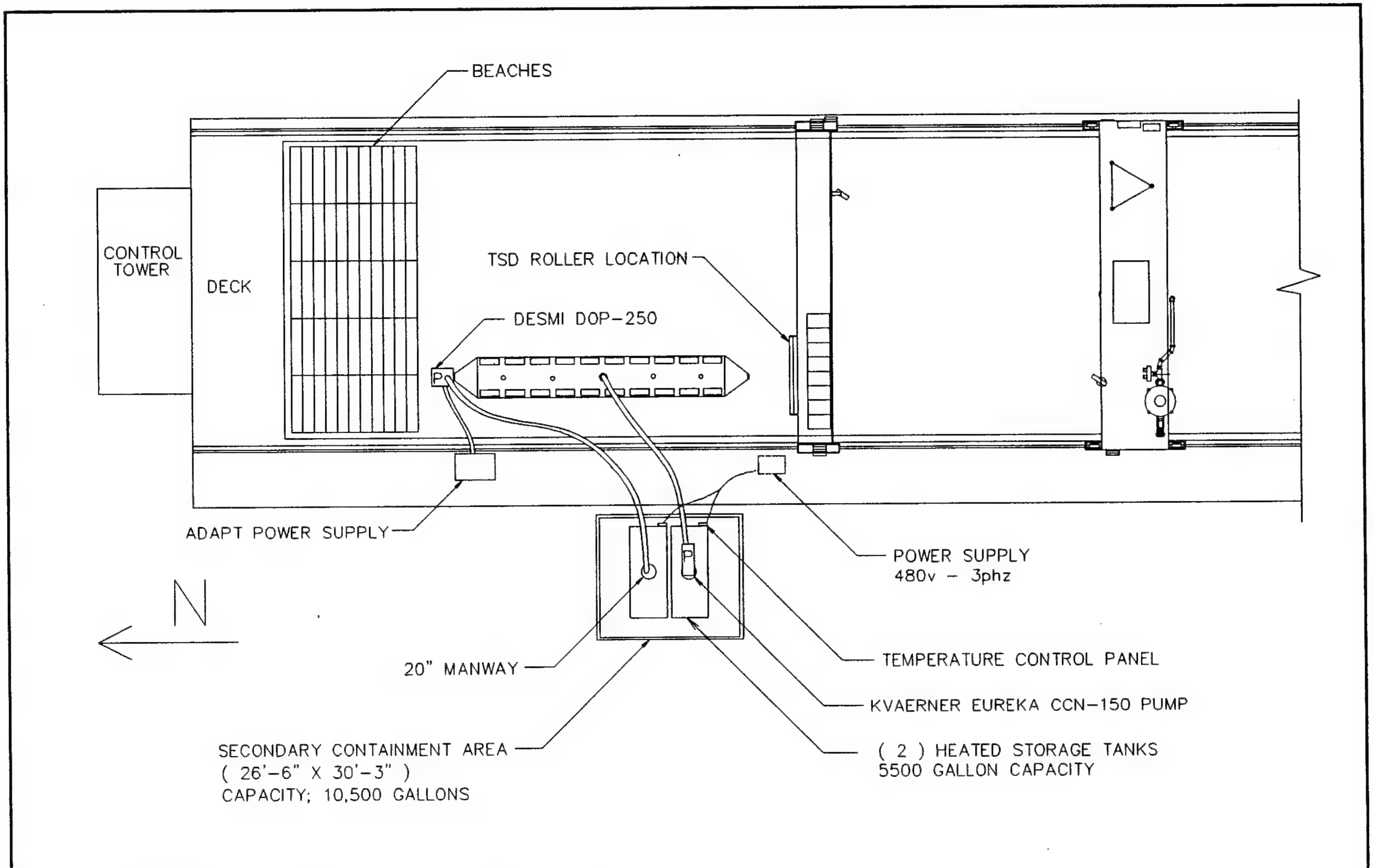


Figure 4 Offloading Test Equipment Setup Plan View

2 TESTING

2.1 Offloading Tests

2.1.1 Test Oils

The oil used for the DOAS offloading tests was Califlux 550 which has a kinematic viscosity of 50,000 cSts at 42°C. Figure 5 is a plot of the viscosity curve for Califlux 550. The main parameter for the offloading test oil was the viscosity. It was desired that the viscosity be close to 50,000 cSts. The storage tanks were capable of maintaining the oil at an elevated temperature which fluctuated around 42°C (107.5°F).

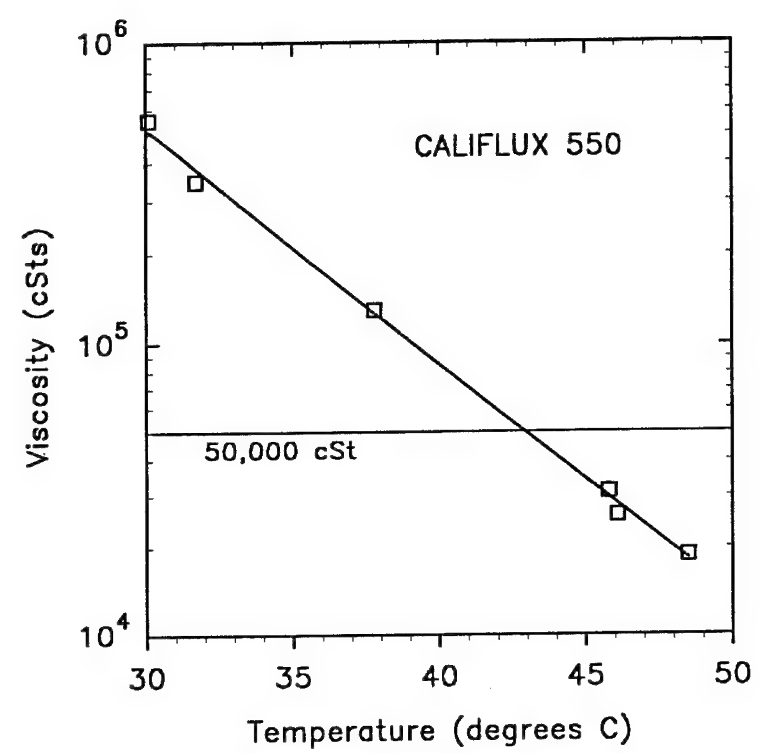


Figure 5 CALIFLUX 550 Viscosity Versus Temperature

The experience with the high viscosity Califlux 550 oil showed that it was difficult and expensive to work with at Ohmsett. As a result, a less viscous oil was specified for the Centrally Located Pump Offloading Tests. This oil was to have a target viscosity between 15,000 and 30,000 cSt at the time of testing and a specific gravity between 0.90 and 0.99. Oil on hand at Ohmsett was to be blended to achieve the target viscosity and specific gravity. However, the maximum obtainable viscosity using oils in Ohmsett's tanks was 2,600 cSt. This was the viscosity actually used.

2.1.2 Test Setup

The basic setup, shown in Figure 4, for the DOAS offloading tests consisted of two 5,500 gallon heated storage tanks in a temporary containment area on the west side of the main basin. These tanks held and heated the oil for the offloading tests. A structure straddled the tanks to support a chain fall for raising, lowering and moving the CCN 150 centrifugal submersible pump from tank to tank. The CCN 150 pump transferred oil from the tanks to the "Sea Slug." The VOSS remote control station, the DOAS remote control station and the diesel hydraulic power pack were all on the west deck of the main basin near the north end. The "Sea Slug" was floating in the main basin and was secured alongside the basin's west wall. The DOAS was attached to the aft end of the "Sea Slug" whose bow end was headed south. All the equipment could be observed from the west deck. A six inch hose carried the oil from the tanks to the "Sea Slug". The fill hose was disconnected and capped after the "Sea Slug" was filled. The volumes transferred to the "Sea Slug" were determined by sounding the heated tanks. The temperature of the oil in each tank was recorded at the time of transfer. The hydraulic lines from the CCN 150 pump were disconnected from the diesel hydraulic power pack after transferring the oil and the hydraulic lines from the DOAS remote control station were connected to the power pack.

For the Centrally Located Pump Offloading Tests, the TSD was moored at the north end of the basin parallel to and alongside the east wall. The TSD was filled with oil initially from the Ohmsett oil storage tanks using oils blended for previous tests. Oil was discharged into the north and south equalization tanks used when skimming oil from the basin. These are immediately adjacent to the east wall of the basin. For the second and third tests of this series, the oil was reloaded into the TSD from the equalization tanks. The equalization tanks were just across the basin wall from the TSD allowing a short run of 6 inch hose from the CCN 150 pump to the tanks.

2.1.3 Offloading Test with DOAS Only (Unassisted)

The setup was as described in the previous paragraphs and no additional equipment or apparatus was required. The testing involved pumping oil into the "Sea Slug" and then measuring what oil was pumped out of the "Sea Slug." The unassisted offloading test was run first - partly as an equipment and procedures check. Of the offloading tests, this was the least complex. In all the offloading tests, offloading continued until, in the view of the test engineer, it was impractical to continue pumping because the pumping rate had dropped too low. Two test runs were made to confirm test results.

2.1.4 Crane Lift Assisted Offloading

In the Crane Lift Assisted Offloading Test the setup was as described earlier except that a crane was used to assist offloading as shown in Figure 6. After the transfer of oil from the storage tanks, a crane attached a line to the bow cone of the "Sea Slug" and the bow of the bag was raised in a series of lifts until the end point of practical offloading. The lifts were based on raising the "Sea Slug" until the crane was lifting 12,000 pounds. When pumping caused the load to drop to 6,000-8,000 pounds, the "Sea Slug" was again lifted until a load of 12,000 pounds was achieved. Pumping did not stop during lifts.

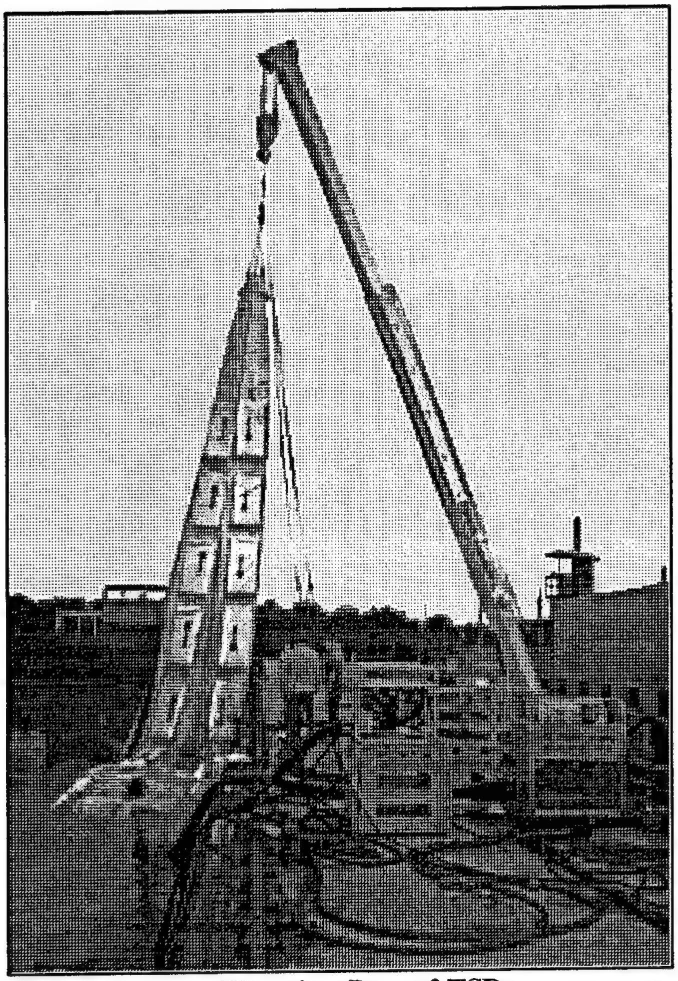


Figure 6 Crane Elevating Bow of TSD

2.1.5 Fairlead Assisted Offloading

The Fairlead Assisted Offloading Tests required a different setup as shown in Figure 7. The approach was to simulate the "Sea Slug" being pulled onboard a vessel by dragging the "Sea Slug" over a fairlead on the stern of the vessel. To simulate these conditions the auxiliary bridge was locked to the rails and the TSD was pulled over the top of the auxiliary bridge using the main bridge. The auxiliary bridge had a pipe fairlead (12" dia., 14 feet long) attached at the walkway level on the north side. A wooden ramp was constructed across the auxiliary bridge forward of the pipe fairlead. A tow line was attached from the bow of the "Sea Slug" across the auxiliary bridge's fairlead and ramp to the center of the main bridge. A load cell was placed inline with the tow line and main bridge.

This arrangement simulated a pull over the stern of a vessel with 12 feet of freeboard. The "Sea Slug" was filled with the required amount of oil, hooked-up to the main bridge and dragged over the fairlead while the DOAS pumped off oil. The main bridge was moved away from the auxiliary bridge until the load cell had a maximum load of 8,000 pounds. As oil was pumped off, the load dropped until the main bridge could be moved forward again.

2.1.6 Weight Assisted Offloading

The Weight Assisted Offloading Test was run with the equipment brought back to the original setup position. The idea behind this test was to add buoyancy to the DOAS end of the "Sea Slug" or add weight to the bow causing the "Sea Slug" to tilt and the oil to collect at the pump because of the difference in specific gravity of the oil and water. Enough buoyant material was not available to lift the stern of the "Sea Slug", therefore, 2,000 pounds of weight was placed on the bow of the "Sea Slug", forcing the bow to the bottom of the basin. This is illustrated in the artists sketch shown in Figure 8. The weights were positioned after the oil was transferred from the storage tanks to the "Sea Slug." The DOAS was started after the "Sea Slug" settled to its new position.

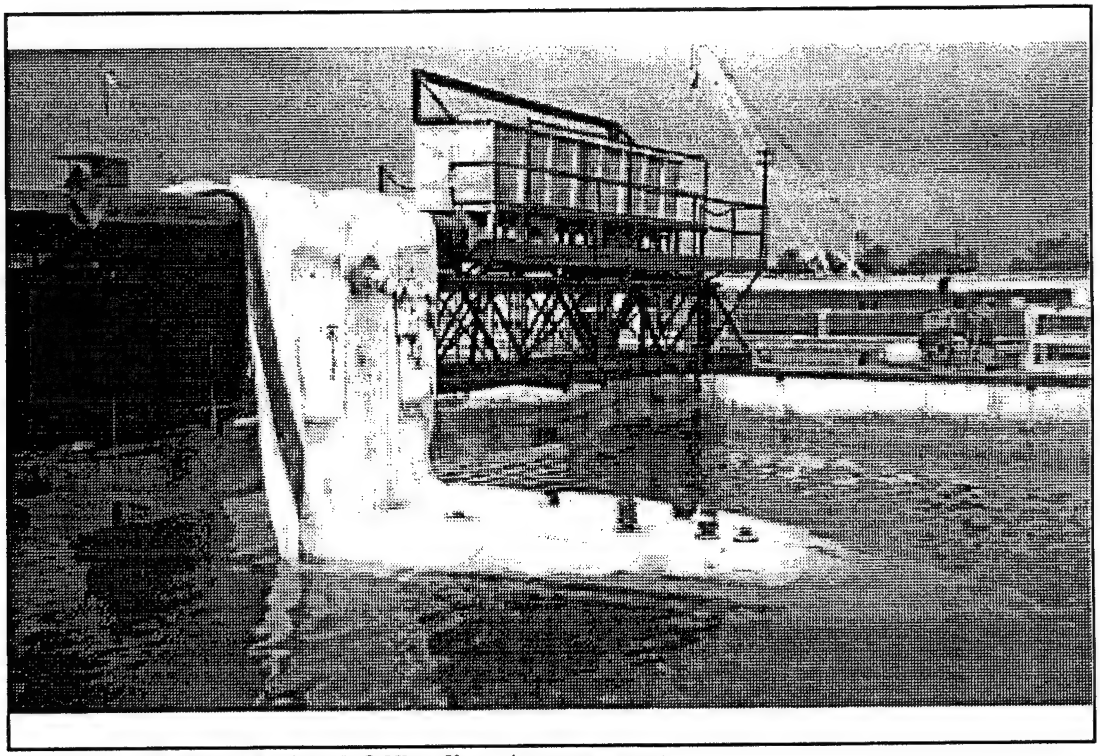


Figure 7 Fairlead Assisted Offloading Arrangement

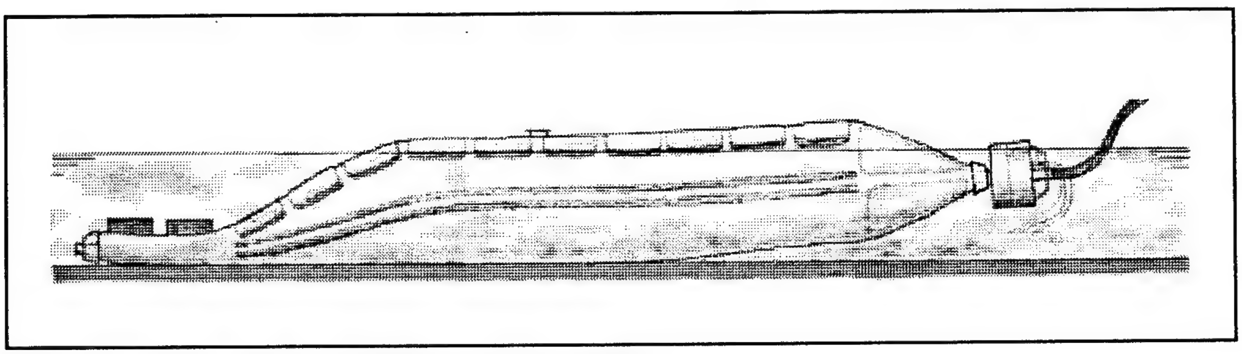


Figure 8 Weight Assisted Offloading Arrangement

2.1.7 Centrally Located Pump Offloading

The pump setup for this test is shown in Figure 3. The intent was to allow the oil to flow from the ends of the TSD to the mid length where the pump was located. The flotation added to the ends of the TSD to improve its towing abilities as a result of the at-sea trials was also expected to benefit this method of offloading by raising the ends of the TSD as fluid was removed. The weight of the centrally located pump was also expected to help by forcing down the middle portion of the TSD. Past experience with similar methods of offloading show that the bag tends to collapse around the pump suction as the bag empties. As a result the bag must be inflated with air to keep the bag away from the pump. The air pressure also assists moving the fluid to the bottom of the TSD. During

cleanup of the DOAS after the offloading tests, the inner liner of the bag had to be cut away from some connections. The liner was still partially intact at the start of these tests and had a large impact on performance in the first run. Remaining pieces of the liner partially blocked the pump suction for the first test. As a result, as much of the liner as possible was removed for the second and third runs with a resulting large improvement in pump performance.

2.2 Decanting Test

The "Sea Slug" was positioned on the east side of basin to provide direct access to the tank farm for loading the "Sea Slug" with the oil/water mixture. The water for the mixture was pumped from the basin and into a "Y" fitting connected to a static mixer and from there into the "Sea Slug." Flow meters were in both the oil and water supply hoses. The flow meters measured the components of the oil/water mixture. Table 1 shows the total of each component and its percent. The Sea Slug's capacity is 25,000 gallons. A total of 20,813 gallons was put into the "Sea Slug" filling it to 83 percent.

Table 1 Oil and Water Mixture

	WATER	OIL	TOTAL
GALLONS	8,960	11,853	20,813
PERCENT OF TOTAL	43%	57%	

The oil used in the mixture was an oil blended from oils on hand at Ohmsett. The oil's viscosity was 850 cps at 25°C (914 cSt) and the specific gravity was 0.93.

The "Sea Slug" was subjected to a harbor chop sea condition prior, during and 10 minutes after filling with the oil/water mixture. The sampling was started 5 minutes after the waves stopped and 15 minutes after the pumping stopped. A series of samples was drawn off every 15 minutes. Five series of samples were taken over one hour from the first series to the last series of samples, which is 75 minutes from when the filling stopped.

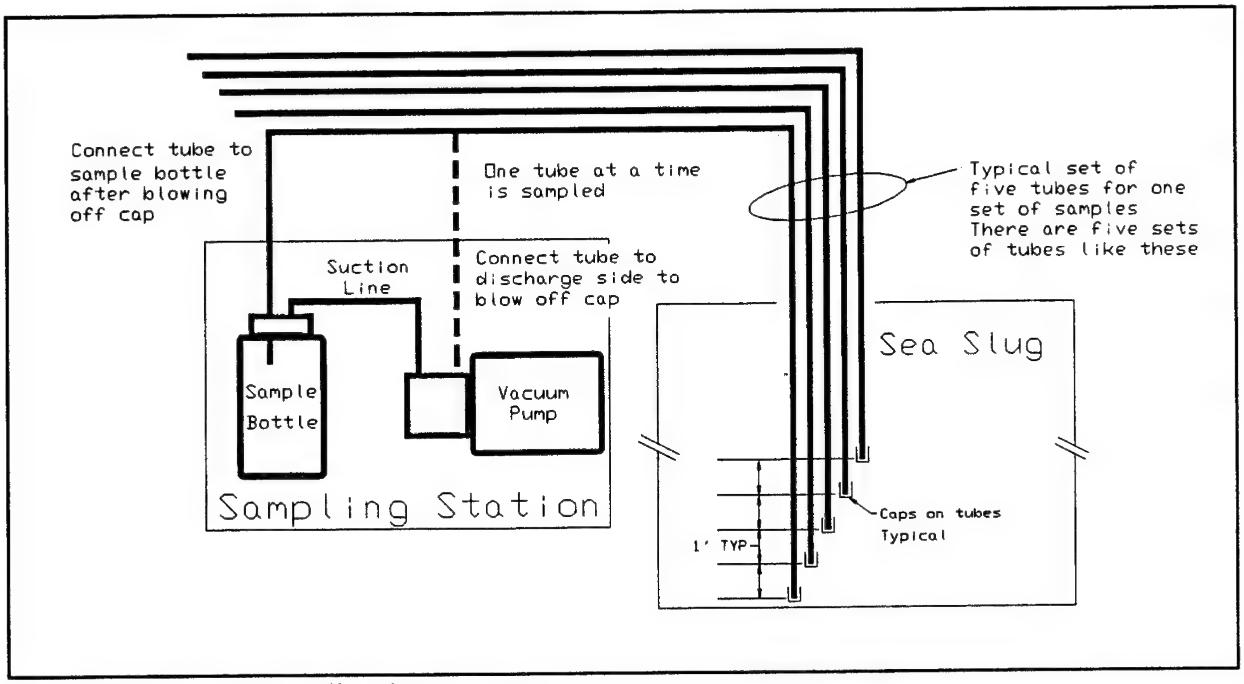


Figure 9 Schematic Sampling Arrangement

The sampling was accomplished by using a sampling apparatus devised for the test. This apparatus is shown schematically in Figure 9. Twenty-five tubes were bundled around a wand and inserted through the center top port of the "Sea Slug." The end of the wand was positioned to the bottom of the "Sea Slug." The 25 tubes were divided into five bundles each with five tubes. The five bundles had one foot separation from each other. This provided five tubes at each level from the bottom to mid center in the "Sea Slug." Each tube had a plug in its "Sea Slug" end. The other end of the tubes were connected to a vacuum pump - one tube at a time. Sampling was started by using the vacuum pump discharge to blow off the tube plugs then using the suction side of the pump to bring up the sample. This was repeated every 15 minutes with a different set of tubes. The above technique prevented contamination of the samples and ensured that the tubes were empty until the time of sampling.

2.3 Cleaning

The manufacturers suggested method of cleaning was to inflate the "Sea Slug" with air pressure and put a cleaning fluid, 100 gallons minimum, inside and roll it around. This cannot be done at Ohmsett because there is not a containment area large enough. Several cleaning companies were consulted as to a solution to the cleaning problem.

The liner of the "Sea Slug" was damaged during the first series of tests and was partially removed during cleaning. This occurred before the first of the centrally located pump tests. Additional portions of the liner were removed after the first test showed that the damaged liner was blocking the pump suction.

3 TEST RESULTS AND CONCLUSIONS

3.1 Offloading Tests

3.1.1 Results

Four different methods for offloading were initially planned. As the results below show, none of these worked well. As a result, a fifth method was added and is also reported here. The first four methods all involved offloading with the DOAS. These were offloading with the DOAS only (unassisted), crane assisted offloading, fairlead assisted offloading, and weight assisted offloading. The fifth method used a centrally mounted pump to offload the TSD.

Table 2 shows the results obtained from the DOAS tests. The unassisted offloading test was repeated to verify the results. This was the first test conducted and much better performance was expected. The second test run confirmed the poor performance of the first run. It was apparent through visual observation that the TSD was collapsing around the pump suction and blocking it. What was suspected by the test team based on the pump performance was that the liner of the TSD was being ingested into the pump. This was confirmed by liner damage witnessed during cleaning after the offloading tests. The pump creates so much suction that oil is not able to flow fast enough from the TSD to the pump. As a result, the sides of the TSD collapse around the suction. The remaining tests with the DOAS were designed to enhance flow of oil in the TSD to the pump.

The fairlead assisted technique worked much better than using the DOAS alone but still did not work acceptably well. Only about half of the initial 10,000 gallon load could be pumped out. Also, the time required was nearly 3½ hours. Again, this result may have been due to the TSD liner blocking the DOAS inlet, but this can not be confirmed. The long offloading time allowed the heated oil to cool resulting in a much more viscous oil at the end than at the start of offloading.

The weigh assisted offloading test worked better than the fairlead assisted method and is easier to implement provided a crane is available. Offloading was faster and less oil was left in the TSD. Liner ingestion was suspected in this test also.

The crane lift method was superior to the other three DOAS methods tested. For practical purposed, all the fluid in the TSD was pumped out in a relatively short time. A full TSD, 25,000 gallons, likely could be emptied in 2 hours by this method. There was no evidence that the liner was being ingested in this test which may explain the improved results. Crane lifts were used on two other occasions to empty the TSD between tests. These were for operational purposes but data was collected on the offloading rates to supplement the data previously collected. In one of these tests, the pump stalled, probably due to liner ingestion. In the other test with very viscous oil, all the oil was emptied but the rate was considerably slower than with 50,000 cSt oil.

Table 2 DOAS Offloading Test Results

TEST	OIL VISCOSITY (cSt)	INITIAL AMOUNT (gallons)	PUMPING TIME (mins)	PUMPED AMOUNT (gallons)	AVERAGE PUMPING RATE (gpm)	PERCENT PUMPED	REMARKS
Offloading w/ DOAS only (Scheduled)	50,000	9,729	---	200	0	2 %	Time not recorded, TSD walls sucked into cone stopping flow almost immediately.
Offloading w/ DOAS only (Repeat)	50,000	10,564	1	Not measured	0	0 %	TSD walls sucked into cone cutting off flow immediately - pump stalled. Believe liner was sucked into pump.
Fairlead Assisted (Scheduled)	50,000 at beginning 200,000 at end	10,235	206	4,815	23	47 %	Pumping stopped - pump stalled. Believe liner caused stall.
Weight Assisted (Scheduled)	50,000	7,054	91	4,945	54	70 %	Pumping stopped - pump stalled. Liner might have caused stall.
Crane Assisted (Scheduled)	50,000	10,564	38	10,564	278	100 %	There was a small residual fluid left. Believe it is oil/water from previous tow test.
Crane Assisted (To Empty)	90,000	9,529	105	6,510	66	68 %	Stopped pumping - pump stalled.
Crane Assisted (To Empty)	200,000 +	---	135	2,598	19	100 %	Pumped to near empty condition.

Table 3 and Figure 10 show the results of the Centrally Located Pump Offloading Tests. The oil used in these tests was less viscous than that used in the tests with the DOAS pump. Oil viscosity was approximately 2,600 cSt versus 50,000 cSt plus for the DOAS tests. In these tests the TSD was pumped down to between 1,150 to 2,450 gallons remaining. However, these numbers are only approximate. They are based on the oil added versus the oil pumped out. There may have been some additional fluid in TSD after each test. Based on these quantities of fluid remaining, between 91 to 95 percent of the contents could be removed from a fully loaded, 25,000 gallon TSD. The offload rate varied from 20 minutes to offload 6,500 gallons in test 2 to 40 minutes to offload the same amount in test 3. However, the added time in test 3 was due to an initially slow pumping rate possibly caused by a clogged pump suction. This was cleared about 12 minutes into the run and the rate for the remainder of the run was similar to that of test 2. The test 3 rate indicates that a full offload (23,000 gallons) would take 2 hours and 21 minutes. The rate for test 2 indicates only half this time would be needed. The test 2 time is the more accurate barring clogging of the pump.

The results from test 1 of the centrally located pump tests should be disregarded. It was found that the partially detached inner liner of the TSD was blocking the pump suction causing a much lower pumping rate than in tests 2 and 3.

Table 3 Centrally Located Pump Offloading Test Results

TEST	INITIAL AMOUNT (gallons)	FINAL AMOUNT (gallons)	PUMPED AMOUNT (gallons)
1	9,450	2,449	7,001
2	8,950	2,196	6,754
3	8,200	1,150	7,050

3.1.2 Conclusions

Although the DOAS can pump the oil reaching it at a reasonable rate regardless of the oil's viscosity, there is a real problem with oil flow to the pump within the TSD. Any method that promotes oil movement towards the DOAS, or any pump, seems to be beneficial. Only the crane assisted lift method provided a practical offloading rate with the DOAS. However, the fairlead assisted and weight assisted results would have been better had liner problems not caused the DOAS to stall. The centrally located pump method worked well as tested (with much less viscous oil) and requires no crane support. The CCN 150 pump was shown in the DOAS tests to be very capable when pumping more viscous oils. The pump should remain in the TSD during loading and towing to be most effective. This eliminates the crane support and time needed to position the pump for offloading.

The liner for the "Sea Slug" was particularly troublesome. It is not adequately attached to prevent it from being ingested by the DOAS. Any liner system must be attached to the outer container sufficiently to prevent pump blockage or pump ingestion. If not, the liner prevents offloading and will be an ineffective barrier if damaged by the pump. The difficulty experienced in cleaning the TSD when used with heavy oils leads to the conclusion that it may be cost effective to replace the

TSD rather than attempt cleaning after a major spill cleanup. If this approach is taken, the liner serves no purpose unless the outer shell will be chemically damaged by the oil. If possible, eliminate the liner.

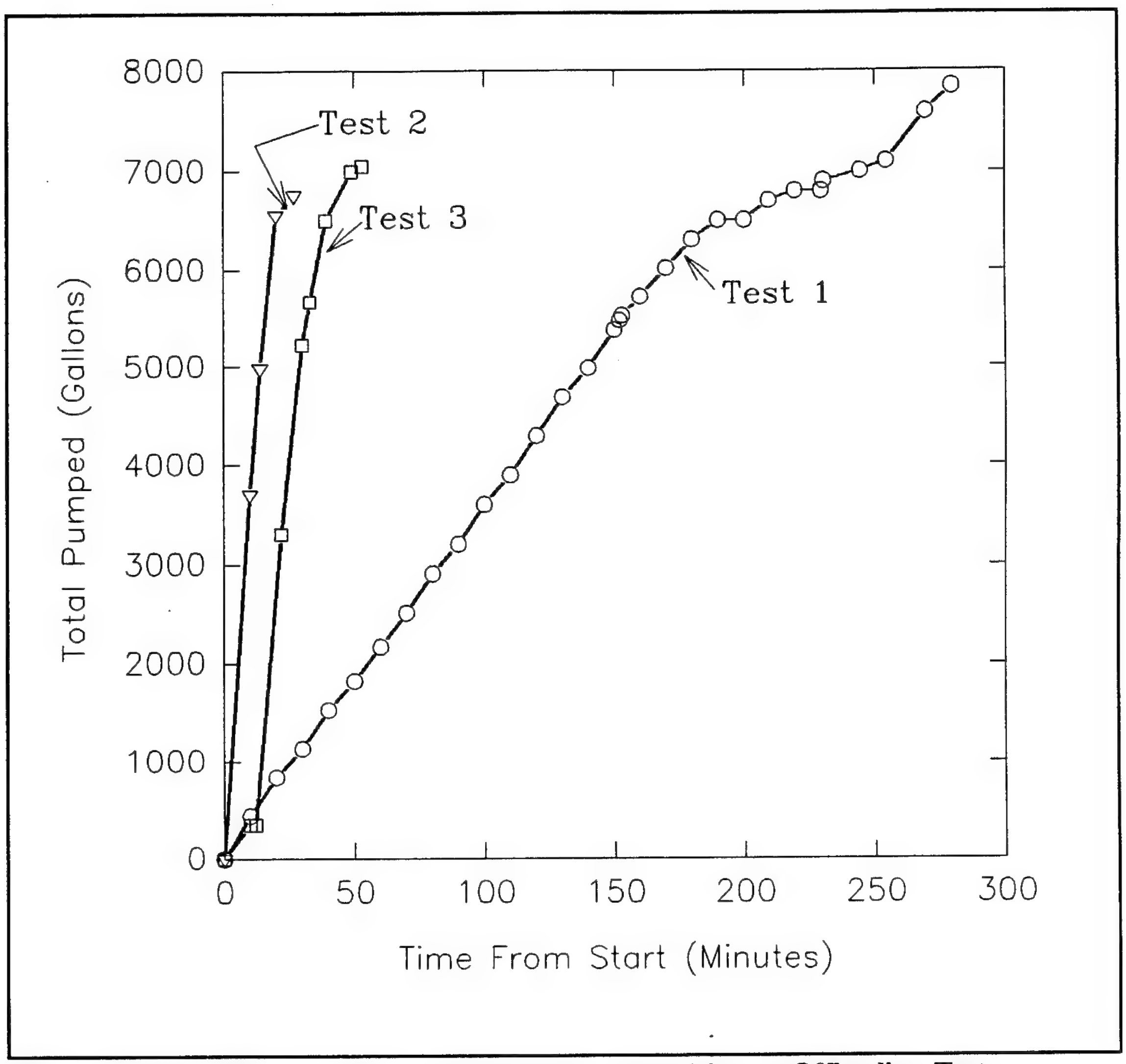


Figure 10 Plot of Discharge Rate for Centrally Located Pump Offloading Tests

3.2 Decanting Test

3.2.1 Results

In the decanting test, samples were taken over a five foot vertical range inside the "Sea Slug." The samples were taken one foot apart with the lowest one foot from the bottom and the highest five feet from the bottom. This range represented 57% of the total height.
Each level was monitored five different times, 15 minutes apart. Samples were identified by numbers for heights with 1 being the lowest and 5 the highest. The levels, 1 through 5, represent the following percent of the "Sea Slug's" volume from the bottom when the "Sea Slug" is 100% full.

Table 4 "Sea Slug" Sampling Levels and Volumes

LEVEL	APPROXIMATE PERCENT OF VOLUME
1	6 %
2	17 %
3	30 %
4	44 %
5	59 %

The samples were analyzed for oil in water using the infrared method with a spectrophotometer. The data is presented on two different graphs due to the large variation in the results. Figure 11 is the graph of the three lower levels measured. Figure 12 is the graph of the two uppermost levels measured. The graphs show no significant change with time in the highest level measured. The other levels go through a significant change in the first three sets of measurements, from 15 to 45 minutes. After one hour a reasonable steady state is achieved.

Since there was 8,960 gallons of water in the mixture tested, this represents 36 % of the volume of the full TSD. Assuming no distortion of the TSD's shape, the fully separated level would be between levels 3 and 4. Ideally, the test results should show 100 % oil at levels 4 and 5 and 100 % water at the three lower levels. Figures 11 and 12 show that by 30 to 45 minutes most of the oil has separated from the water. However, at level 4, there is still a great deal of water held in the mixture that doesn't separate over time.

3.2.2 Conclusions

The lower portion of the liquid in the TSD could be decanted off on site provided that water with 1 part per 1000 of oil can be discharged. There is not a sharp break line between oil and water but the amount of oil in the water below the theoretical break line does fall off very rapidly after a short settling time. The fluid remaining after decanting can be expected to have between 20 to 80 percent water in it. Much of this water may be held in an emulsion with the oil.

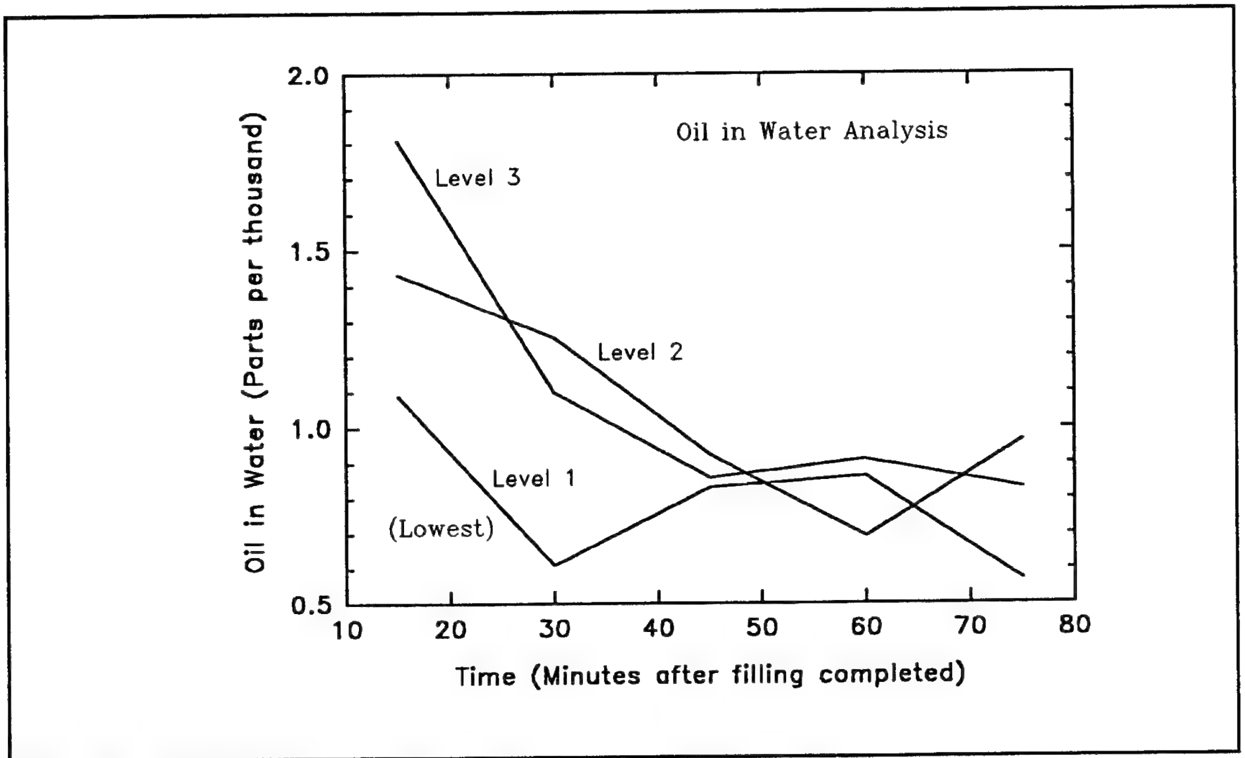


Figure 11 **TSD Oil Separation Test - Three Lower Sample Levels**

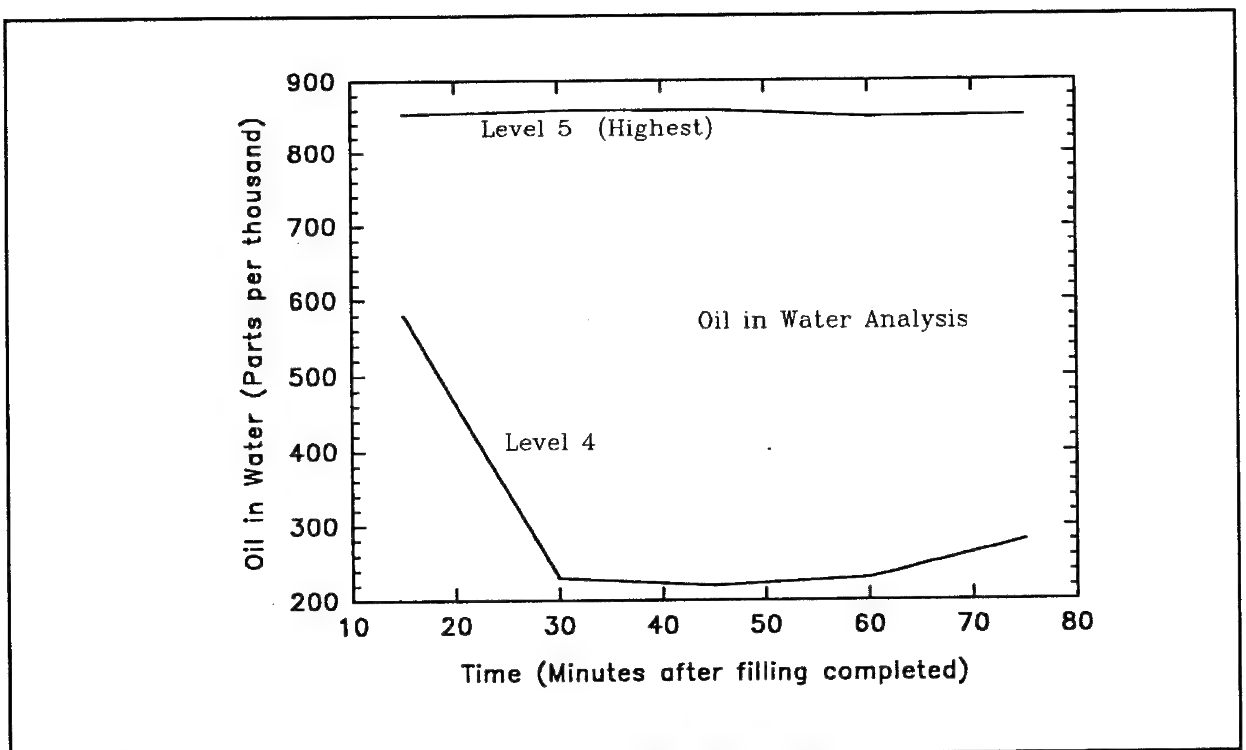


Figure 12 **TSD Oil Separation Test - Two Upper Sample Levels**

3.3 Cleaning

3.3.1 Results

Cleaning of the Sea Slug consists of two different procedures. Different techniques were needed for the exterior and interior surfaces. In addition, the large size required different approaches to manipulating the Sea Slug while cleaning.

To clean the exterior surfaces, the Sea Slug was flattened out and the exposed surface was cleaned with fresh water and cleaning solutions. It was then rinsed with a power washer. One end was lifted by crane and folded over, exposing the underside. This side was then cleaned as the top had been. After all the exterior surface was initially cleaned, a final rinse was done with the Sea Slug inflated with air. One day was required for the exterior cleaning. Crane services were required to flip the TSD over.

The interior surfaces were expected to be difficult to clean. Therefore, several cleaning companies were contacted for suggestions. They all had suggestions for cleaning the outside surface with their products, but no viable method was suggested for cleaning the inside surface. The Sea Slug manufacturer's suggestion was to pump in a mixture of water and detergent, then fill the TSD with air, and then roll the inflated Sea Slug around. The last step consisted of emptying the Sea Slug by lifting one end with a crane. Their method could not be implemented because of the limited contained space and the number of personnel required. The floatation on the TSD prohibits it from being rolled in the tank to agitate the cleaner inside.

The method that we used was similar to the manufacturer's suggested method. A mixture of water and cleaning solutions was injected into the interior of the bag and then the TSD was partially filled with air. The Sea Slug was then lifted from one end in small increments until the liquid was discharged from the other end. This was repeated until there was no evidence of oil in the discharged liquid. A total of three days was required to clean the interior. A crane was required throughout this period to lift the TSD.

The lining impeded the cleaning by bunching up at the exit and blocking the removal of oil and cleaning liquid. The liner had to be pulled through the exit port and cut off. After cutting the liner, the cleaning process described above was successful. All of the cleaning was done after the lining was cut out. Later, it was found that the liner is not intended to remain in the TSD during cleaning. It is to be discarded.

Two cleaning solutions were used. Both cleaned well when mixed with water. Each solution was used independent of the other. The cleaning solutions were: Moncosolve 210 by INDCO, Inc., and Grancontrol O by C&A Products, Inc.

3.3.2 Conclusions

As during offloading, the liner was found to hamper the cleaning process for the interior of the Sea Slug by blocking the exits for fluid. The size of the Sea Slug was also a factor that slowed the cleaning process. A crane with a sixty foot lift and 2,000 pound plus capacity is needed to handle the

Sea Slug effectively. Smaller TSDs would require smaller cranes and be less cumbersome to handle.

Normal cleaning procedures using water, cleaning solution, and power washing cleaned the exterior surfaces well as long as the Sea Slug could be manipulated to expose the exterior surface for cleaning. The interior surface required repeated flushing along with enough time for the flushing liquid to emulsify the residual oil.

A total of four days were required for cleaning and a crane had to be used through much of this period. Cleaning of equipment can be a significant time and cost issue after a spill.

4 OBSERVATIONS AND COMMENTS

During the testing of the "Sea Slug" several observations were made which may be of interest. First, the CCN 150 pump worked very well in transferring oil from the storage tanks to the "Sea Slug." It pumped 50,000 cSt oil at 150 gpm. This is better than the advertised output.

The diesel hydraulic power pack for the DOAS pump was observed to provide a hydraulic flow between 34 gpm and 4 gpm. At 4 gpm the DOAS pump stalled. During offloading, the DOAS pump was operated at the maximum flow of 34 gpm. As the oil viscosity increased, the flow to the DOAS dropped off as expected.

After the DOAS offloading test period, it was noted that approximately 700 gallons of water had entered the "Sea Slug." A portion of this water may have been in the "Sea Slug" from the previous tow test. A very light coating of water left in the TSD could result in 200 to 300 gallons of water. Other water entered when the output hose was blown off of its fitting. The DOAS pump was reversed to stop oil loss until the knife valve could be closed.

Finally, it is a suggestion that the "Sea Slug" be emptied from as close to the bottom as possible. In an oil/water situation the decanted water would then be pumped off first.

5 TSD TEST QUALITY

5.1 Introduction

TSD Test Quality is the active application of the Ohmsett "General Quality Procedures and Documentation Plan Manual." This Plan is implemented by means of the "TSD Quality Checklist." (See 5.12)

This Checklist has a list of those items in the TSD Test Plan that are deemed important elements in creating a quality test. This list was used by the Ohmsett QC Officer, and the TSD QA Engineer to record spot checks of key quality elements, along with appropriate comments, where necessary. A description of these key quality elements follows.

5.2 Procedures

The TSD Quality Checklist was implemented as follows:

The TSD Quality Checklist consists of a complete list of quality concern items. The Ohmsett QC officer or the QA Engineer used the checklist to spot check items, and confirm adherance to the TSD test plan. This checklist is used before, during, and after the test to make sure all areas of the test plan receive the same through quality attention.

The principal areas of the test plan that received attention were:

A. Initial calibration data
B. Pre and post test checks and conditions
C. Test checks and conditions
D. Sampling
E. Significant occurrences/variations
F. Data reduction/validation
G. Data accuracy/precision
H. Documention of the test
I. Test report

5.3 Initial Calibration Data

A check was made to ensure that data was available to show the initial source of calibration data for each piece of instrumentation used in the test. This included any calibration information necessary to bring the calibration data up to date for this test.

5.4 Pre and Post Test Checks and Conditions

These are checks that were performed on the instrumentation daily in the morning before testing started and at the end of the day when testing stopped. This was done on all days that testing occurred. Notes were made of any unusual conditions that occurred. Conditions were evaluated before testing started or, if noted at the end of the day, the day's data was examined to determine it's validity and whether the affected tests needed to be repeated.

5.5 Test Checks and Conditions

These checks ensured that the test plan's instructions were followed and that the records made during the test were completed accurately.

5.6 Sampling

Sampling was checked for compliance with the instructions in this plan under "Fluid Measurement, Sampling, and Testing Procedures."

5.7 Significant Occurrences/Variations

This part of the TSD Quality checks were concerned with recording any significant occurrences/variations that occurred during the TSD tests.

5.8 Data Reduction/Validation

Checks were made by the QA Engineer according to instructions in the "Analysis of Test Data" of this plan. This verified that the data reduction was according to the TSD plan and the data produced was valid.

5.9 Data Accuracy/Precision

Data accuracy/precision was addressed by using the instructions in the "Analysis of Test Data" section of the test plan. Checks were made to assure these instructions were followed. Checks were also made to ensure that this issue was addressed in the Final Report.

5.10 Documentation of Test

Instructions to ensure proper test documentation are described under "Documentaion of Testing" in the test plan. Checks were made to assure these were followed.

5.11 Test Report

The Test Report was checked to ensure that the elements of the test plan under the section "Test Report" were included.

5.12 TSD Quality Checklist

The next pages provide the TSD Quality Checklist used. This checklist supports the quality requirements of the TSD Test Plan. This checklist was filled out before, during, and after the testing and involved all areas of the TSD Test Plan.

TSD QUALITY CHECKLIST

Project: TSD

Project No.:__________

Test Plan (and any changes thereto)   Approved: __________ Verified by   __________ Date

Pretest Conditions:	Time	Verified by	Date
Weather Conditions:			
Air Temp.	_____	________	___
Water Temp.	_____	________	___
Wind Speed	_____	________	___
Wind Direction	_____	________	___
Underwater Camera Operational	_____	________	___
Above Water Camera(s) Operational	_____	________	___
Test SetUp Per Dwg/Sketch *	_____	________	___

* If modified, show modification and attach sketch to checklist and so note.

Calibration Data:	Calibration Sat.	Verified By	Date
Bridge Speed	________	________	___
Bridge Distance	________	________	___
Wave Frequency	________	________	___
Wave Height Probe	________	________	___
Pressure Probe 1	________	________	___
Pressure Probe 2	________	________	___
10K Load Cell	________	________	___

Test Conditions

Test Set Up Per Plan/Sketch; Performed in Accordance with Plan

Run # **	Time	Verified By	Date
________	_____	________	_____

TSD QUALITY CHECK LIST

Test Conditions

Run #	Time	Verified By	Date
______	____	_______	___
______	____	_______	___
______	____	_______	___

** Need Not Be Performed For Each Run, Select Randomly And Identify Runs Chosen

Sampling

Type of Sample	Run No.	Sample ID	Taken By	Date/Time
________	_____	______	______	_______
________	_____	______	______	_______
________	_____	______	______	_______
________	_____	______	______	_______
________	_____	______	______	_______
________	_____	______	______	_______

Verify Proper Sampling On A Random Basis.

Significant Occurrences/ Variations

Test ID No. ______
Run No. ______
Description of Occurrence/ Variation:______________________________
____
____
____

Reported By__________ Date/Time______

Post Test Conditions	Time	Verified By	Date
Weather:			
Air Temp.	_____	_________	_____
Water Temp.	_____	_________	_____
Wind Speed	_____	_________	_____
Wind Direction	_____	_________	_____
All Required Tests Completed	_____	_________	_____
Required Test Data Available	_____	_________	_____